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Original Research

Water Pollution and Water Quality Assessment of the Way Kuripan River in Bandar Lampung City (Sumatera, Indonesia)

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Abstract

The Way Kuripan River is an important water resource in Bandar Lampung City. However, its quality deteriorates continuously due to land use change accompanied by housing expansion and open areas. This study aims at analyzing its water quality and pollution level based on the present land-use zoning. Three zones are determined based on the dominant land use covering the riverbank sides. Water sampling was carried out at nine settling points (3 samples per zone) to measure the level of BOD_5, COD, TSS, *Escherichia coli* contends, and also Pollution Index (PI), as well as the Biodegradable Index (BI). The results showed that the water has been experiencing pollution for grade-C river overall data. However, based on the zoning, all of the parameters of the upstream sides are below quality standard (QS), while at the middle stream, the BOD_5 has exceeded QS (21.9-26.4 mg/L), whereas at the downstream, the parameters of BOD_5, COD, and *Escherichia coli* have exceeded from the QS. The PI and BI values indicated moderately polluted downstream, with the average biodegradable. For this reason, paying attention to land use change is important to assess the level of river pollution. The study results also found that organic matter from domestic is the primary pollutant of the river. Therefore controlling the upstream in accordance with regional spatial planning regulations and followed by a conservation movement as well as change people's behavior to be more caring about environmental management for catchment areas are the urgent actions for restoring and improving the river water quality.

Keywords: BOD, COD, *Escherichia coli*, pollution, river, TSS

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Introduction

The exponentially high rate of population growth and the urbanization impact on the increasing demand for residential land [1-4] as in Bandar Lampung City, Indonesia. In turn, it will also trigger land cover degradation from covered with vegetation to open land which eventually becomes urban areas such as settlements and other built areas. In line with this land use change, according to [4] in developing countries, the urban population has increased by 48%, living in some congested and unplanned areas so that public authorities are generally experiencing difficulty in providing public services. The proportion of the population living with this condition in developing countries is about 30% of the population living in urban areas under the status of informal settlement [5]. Therefore they are always in a condition of vulnerability to various livelihood problems and other social problems. The United Nations defines the vulnerability of informal settlements, including the shortage of clean water, proper sanitation, security of tenure, inadequate living space, and low quality of buildings [4, 6].

The increment in population growth is also followed by increased human activities that produce domestic waste and make the pollutant burden bigger and bigger from time to time [7]. In addition, the amount of pollutants is closely related to household income [8]. An increase in the pollutant load will certainly reduce the water quality, especially when uncontrolled waste disposal accumulated in river body, that suppress the river's carrying capacity to assimilate pollutant. Sources of pollution in all rivers are mainly wastewater discharge from households, washing toilets [9], surface runoff from agricultural areas and roads network, as well as the leachate from garbage disposal [10]. About 50% of the pollution load discharged by rivers is caused by urban wastewater from households [11]. This river burden will escalate in line with depleting stream flow induced by global warming and climate change phenomena [12].

As a particular type of surface water, the river, apart from being one of the typical characteristics of water flow, also have features that only belong to it. The velocity of the water flow influences the mixing of water across the river profile, the increase in soil erosion through which rivers pass, and the threat of eutrophication is lower than that of lake waters. Rivers can also transfer contamination over long distances, especially those not reduced in the self-cleaning process, e.g., heavy metals [13].

Housing development on the riverbanks is a serious problem in several countries. The land use change for housing allocation has decreased river water quality, especially from household waste directly discharged into the river [14, 15]. Domestic pollutants are generally biological from the kitchen, washing, and toilet waste. The study results of Gu et al. [16] found that the direct emission of domestic waste was about 20 million tons per day, the annual COD emission was about 10.69 million tons, and the annual ammonia nitrogen emission was 0.73 million tons. Disposal of effluents contributes to the oxygen demand and nutrient loading of the waters, promotes toxins and algae growth, and leads to unstable aquatic ecosystems [17].

The Way Kuripan River has an essential role for all people's life activities in Bandar Lampung City because it is a source of clean water treatment (WTP). River water sourced from Wan Abdul Rachman Forest Park with a width of about 10.0 m upstream and about 20.0 m downstream, flows along 9.6 km on the city's outskirts and empties into Lampung Bay [18]. Population growth and migration flows have changed the function of land in the MS zone into open and residential areas.

Until now, the local government's assessment of river water quality has only been carried out in the downstream (DS) section to determine the level of water pollution. Meanwhile, water quality is strongly influenced by human activities along the river. Water assessment and monitoring parameters are very important to maintain public health and the environment [19]. This study aims to analyze the quality and level of water pollution of the Way Kuripan River in three zones based on riverbank land use. Measurement of the parameters BOD_5, COD, TSS, and *Escherichia coli* and the assessment of the Pollution Index and Biodegradable Index.

Material and Methods

Study Site and Setting

The research was conducted along the Kuripan river, Bandar Lampung City. Nine points were determined purposively, representing three zones: upstream (US), middle stream (MS), and downstream (DS). The US zone (approximately 3 km) represents a river basin, predominantly an agricultural area with little low population occupancy. The physical quality of river water is clear, odorless, and flows smoothly. The MS zone (approximately 3 km) passes through a mixed area of plantations, new settlements, and open land. The water in this zone is also used as raw water for drinking water treatment owned by PDAM Way Rilau, Bandar Lampung City. The DS zone (3.6 km) is densely populated, and the river water looks cloudy and odorous.

Sampling

Sampling method refers Indonesia National Standard [20] carried out from May to June 2020. The month without rain is chosen to avoid the effect of diluting rainwater and erosion. A total of 2 liters of river water was taken in sterile, opaque plastic containers at each predetermined point. All samples were brought at cold temperature (ice-box) for

Table 1. Coordinate sampling (DMS).

Sampling Point	Coordinate
Upstream-1 (US-1)	5°26'06" S 105°14'11" E
Upstream-2 (US-2)	5°26'03" S 105°14'21" E
Upstream-3 (US-3)	5°26'08" S 105°14'30" E
Middle stream-4 (MS-4)	5°26'16" S 105°14'44" E
Middle stream-5 (MS-5)	5°26'29" S 105°15'02" E
Middle stream-6 (MS-6)	5°26'46" S 105°15'13" E
Downstream-7 (DS-7)	5°26'03" S 105°15'23" E
Downstream-8 (DS-8)	5°27'10" S 105°15'38" E
Downstream-9 (DS-9)	5°27'15" S 105°15'47" E

examination of Biochemical Oxygen Demand (BOD_5), Chemical Oxygen Demand (COD), Total Suspended Solid (TSS), *Escherichia coli (E. coli)*. The nine sampling points (three per zone) are shown in Table 1 and Fig 1.

Analysis Water Samples

Reagents for water quality examination such as $MnSO_4$, KOH, KI, H_2SO_4, $Na_2S_2O_3$, $K_2Cr_2O_7$ were obtained from Sigma Aldrich. Lactose Broth (LB) and Brilliant Green Bile Lactose Broth (BGLB) from Merck. All these reagents are analytical grade and are applied directly. All solutions were prepared with deionized water. In addition to glassware from Pyrex, the equipment used is a spectrophotometer (DLab Model SP-UV1100), dry oven (Drawell Model 9030A), incubator (Biostellar Model BS-LI 2500), and analytical balance (Shimadzu Model AP225WD).

A 500 mL of sample was put into two Winkler bottles (250 mL). One bottle was for immediate Dissolved Oxygen (DO) examination, and another bottle was stored (20°C) for examination on the fifth day. The results of both examinations were used to measure the BOD_5 parameter. The measurement uses the iodometric titration method refers Indonesia National Standard [21]. The BOD_5 values are (Eq. 1):

$$BOD_5\ (mg/L) = \frac{(A1-A2)-\left(\frac{B1-B2}{VB}\right)VC}{P} \quad (1)$$

where, BOD_5 = sample BOD_5 value (mg/L), A_1= DO sample before incubation 0 days (mg/L), A_2 = DO sample after 5 days incubation (mg/L), B_1 = DO blank before incubation 0 days (mg/L), B_2 = DO blank after 5 days incubation (mg/L), V_B = volume of microbial suspension in blank DO vial, Vc = volume of microbial suspension in test sample vial, P = sample volume ratio (V_1) per total volume (V_2).

COD measurement with closed reflux method by Spectrophotometry refers Indonesia National Standard [22]. 2.5 mL of the sample was put into a closed reflux tube with a Sulfuric acid reagent and heated for 2 hours. The color of the solution was measured by a spectrophotometer (600 nm) and compared with a standard curve. COD value is determined by Eq. (2), Eq. (3), Eq. (4):

$$a = \frac{(\sum yi-(b\sum xi)}{n} \quad (2)$$

$$b = \frac{\sum xiyi-\frac{\sum xiyi}{n})}{\sum xi^2-(\sum\frac{xi^2}{n})} \quad (3)$$

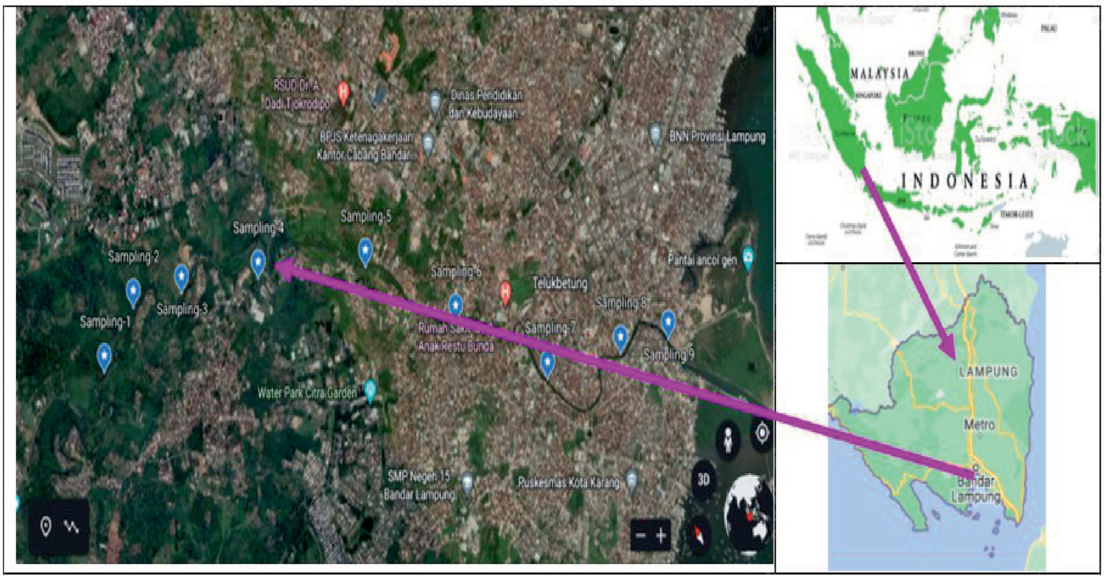

Fig. 1. Geographic location of the study area in Way Kuripan River.

$$\text{COD (mg/L)} = \frac{y-a}{b} \quad (4)$$

where, a = value a, b = value b, x = sample concentration (mg/L), y = sample absorbance (A).

TSS measurement using the gravimetric method refers Indonesia National Standard [23]. 25 ml of the sample was filtered with Whatman (0.1 mm) and dried in a dry oven (105ºC for 1 hour). The difference weight was expressed as the TSS value (Eq. 5).

$$\text{TSS (mg/L)} = \frac{(A-B).1000}{sample\ volume\ (mL)} \quad (5)$$

where, A = weight of filter paper + dry residue (mg), B = weight of filter paper (mg).

The Most Probable Number (MPN) method of three series of double tubes (0.1 mL, 1.0 mL, and 10 mL) was used for the assessment of *E. coli* in samples, refers Indonesia National Standard [24]. MPN is a statistical method based on the random dispersion of microorganisms per volume in a given sample. Two test steps were applied (presumptive and confirmed test), then compared with the MPN table.

Pollution Index (PI) to determine the pollution level relative to the permitted water quality parameters. PI is determined for a designation; it can be developed for several purposes for all parts of a water body or part of a river [25]. PI calculation with the formula (Eq. 6):

$$\text{PI} = \sqrt{\frac{(\text{Ci/Li})\text{average}^2 + (\text{Ci/Li})\text{maximum}^2}{2}}$$

$$(\text{Ci/Li})_{\text{maximum}} = 1 + 5\ \text{Log}\ (\text{Ci/Li})_{\text{average}},\ \text{if (Ci/Li)} > 1;$$
$$(\text{Ci/Li})_{\text{maximum}} = (\text{Ci/Li})_{\text{average}},\ \text{if (Ci/Li)} < 1; \quad (6)$$

where L_i = concentration of water quality parameters listed in the water quality standard; C_i = concentration of water quality parameters measured; PI = Pollution index for the designation; $(C_i/L_i)_{average} = C_i/L_{i\ average}$, $(C_i/L_i)_{maximum} = C_i/L_{i\ maximum}$. Interpreted of PI:≤1.0 Good; 1.0<IP≤5.0 Low polluted; 5.0<IP≤10.0 Medium polluted; P>10.0 Heavy polluted.

Biodegradable Index (BI) is the ratio of BOD_5 and COD to measure biodegradability [26-28]. The BI is calculated using Eq. (7):

$$\text{Biodegradable Index (BI)} = \frac{BOD}{COD} \quad (7)$$

Interpreted of IB:≥0.5 easily biodegradable; 0.4≥BI<0.5 average biodegradable; 0.2≤BI<0.4 slowly biodegradable; < 0.2 not biodegradable.

River classification (Table 2) follows Government Regulation [29].

Results and Discussion

Parameter measurement results (Table 3) show that the average BOD_5 is 21.3 (2.3-37.7) mg/L; it has exceeded the QS grade-C river (6 mg/L). Average COD showed 44.1 (6.2-86.0) mg/L, smaller than QS (50 mg/L). Table 3 also shows the results of TSS and *E. coli* measurements. Overall, TSS in Way Kuripan River water is still smaller than QS, 115.0 (40.0-270.0) mg/L. Meanwhile, the average number of *E. coli* was also smaller than QS (1107.9 MPN/100 mL).

Fig. 2 shows the results of parameter measurements based on sample points for each zoning, then compared with QS. In the US zone (samples 1-3), BOD_5 was between 2.3-5.0 mg/L, COD 6.2-6.7 mg/L, TSS 40.0-50.0 mg/L, and *E. coli* 24.0-152.0 MPN/100 mL. Overall measurements show below QS for grade-C rivers.

In the MS zone (samples 4-6), BOD_5 was between 21.9-26.4 mg/L, COD 34.4-45.8 mg/L, TSS 70.0-105.0 mg/L, and *E. coli* 350.0-1100.0 MPN/100 mL. Comparing QS, the BOD_5 parameter has exceeded, but the TSS and *E. coli* COD parameters are still below QS. In the DS zone (samples 7-9), BOD_5 was between 36.9-37.7 mg/L, COD 79.6-86.0 mg/L, TSS 170.0-270.0 mg/L, and *E. coli* 240.0 MPN/100 mL. Overall parameter measurements show above QS for grade-C rivers.

The PI assessment was carried out based on US, MS, and DS zones (Table 4). In the US zone (samples 1-3), the PI value is 0.22. These results indicate that the river water quality is in a Good category. In the MS

Table 2. Classification for rivers.

Parameters	Grade-A	Grade-B	Grade-C	Grade-D
BOD_5 (mg/L)	2	3	6	12
COD (mg/L)	10	25	50	100
TSS (mg/L)	50	50	400	400
E.coli (MPN/100 mL)	100	1000	2000	2000
Designated beneficial water uses	Water treatment plant.	Tourism, freshwater fish farming, farm, irrigation.	Freshwater fish farming, farm, irrigation.	Plant irrigation.

Table 3. Parameters measurement result.

Parameters and Quality standard	BOD_5 (mg/L)	COD (mg/L)	TSS (mg/L)	*E.coli* (MPN/100 mL)
Mean	21.3	44.1	115.0	1107.9
Minimum	2.3	6.2	40.0	23.5
Maximum	37.7	86.0	270.0	2400.0
Quality standards for rivers C-grade*	6.0	50.0	400.0	2000.0

**Quality standard according Government Regulation [29]

Table 4. Pollution Index and Biodegradable Index of Way Kuripan River.

Zone	Parameter	Ci	Li	Ci/Li_{avg}	Ci/Li_{max}	$PI_{parameters}$	PI	BI
US	BOD_5	3.7	6	0.62	0.62	0.62	0.22	0.59
	COD	6.4	50	0.13	0.13	0.13		
	TSS	43.3	400	0.11	0.11	0.11		
	E.coli	73.8	2000	0.04	0.04	0.04		
MS	BOD_5	23.4	6	3.91	3.91	3.91	1.35	0.56
	COD	42.0	50	0.84	0.84	0.84		
	TSS	90.0	400	0.23	0.23	0.23		
	E.coli	850.0	2000	0.43	0.43	0.43		
DS	BOD_5	36.8	6	6.14	4.94	5.57	2.32	0.44
	COD	83.9	50	1.68	2.12	1.91		
	TSS	211.7	400	0.53	0.53	0.53		
	E.coli	2400.0	2000	1.20	1.40	1.30		
Total	BOD_5	21.3	6	3.56	3.75	3.66	1.33	0.48
	COD	44.1	50	0.88	0.73	0.81		
	TSS	115.0	400	0.29	0.29	0.29		
	E.coli	1107.9	2000	0.55	0.55	0.55		

zone (samples 4-6), the PI values were 1.35, it shows that river water has been polluted in the Low polluted category. While the calculation results in the DS zone (samples 7-9), the PI value has reached 2.32, also included in the category of Low polluted. Overall, Way Kuripan River's IP is 1.35, in the Low polluted category.

Fig. 3a) is the trend of PI values based on zoning compared to the overall value. These results indicate that the further downstream, the more polluted the river water. In the US zone, the river water is still not polluted, while the MS and DS zones show low polluted. However, river water is categorized as low polluted using all the data.

BI is the ratio of BOD_5 and COD as a measure of biodegradable ability. The measurement results (Fig 3b) in the US zone get a BI value of 0.59 (easily biodegradable), MS is 0.56 (easily biodegradable), and DS is 0.44 (average biodegradable). The results of this study indicate that the quality of river water is decreasing based on zoning. Overall, the BI of Way Kuripan river water is 0.44 (average biodegradable).

Fig. 4 shows the PI of each parameter by zone and total. In the US zone (Fig. 4a), the PI values of each parameter and the total are still less than one. These results indicate that the US zone still has a good ecological system and is not polluted. In the MS zone (Fig. 4b), the BOD_5 parameter has exceeded the limit value (PI = 3.91), while the other parameters are still below the limit value (PI<1). These results explain that pollution begins to occur in the MS zone. Pollutants are organic, considering the value of IP parameter COD <1.

The DS zone (Fig. 3c) shows PI>1 values for BOD_5, COD, and *E. coli* parameters. These results explain that the pollutant is in the form of organic, inorganic, and feces. Specifically, the PI value for the BOD_5 parameter reached 5.57, indicating a very high biological load

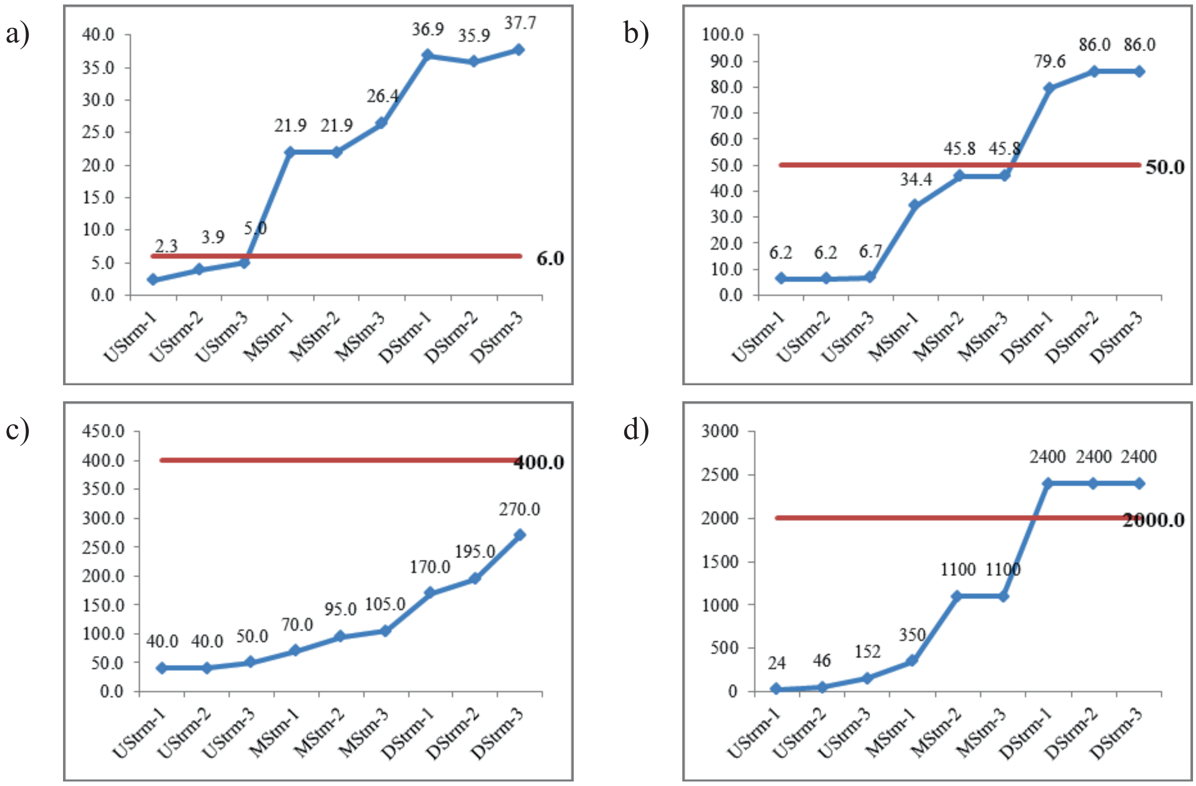

Fig. 2. Parameter value by sample point. a) BOD_5. b) COD. c) TSS. d) *E. coli.*

on the aquatic system. This can be influenced by the decrease in decomposing bacteria due to the entry of toxic materials, marked by a significant increase in COD.

Overall (Fig. 3d), only the IP value of the BOD_5 parameter exceeded one (IP =3.66). The result shows that the pollution of the Way Kuripan River is generally caused by organic matter.

BOD_5 is one of the most widely used criteria for water quality assessment. It provides information about the biodegradable fraction of the organic load in the water. High concentrations of BOD_5 reduce the availability of oxygen for microbiological activity [28]. BOD_5 is also defined as a response to the entry of biodegradable organic matter. These organic materials can be in the form of fat, protein, starch, glucose, aldehyde, and ester [30].

The results of the BOD_5 measurement (Fig. 2a) in the US section were still low, at 3.3 (2.3-4.0) mg/L. Then it increased about eight times to 23.4 (21.9-26.4) mg/L in the MS zone and finally increased about 12 times in the DS section to 36.8 (36.9-37.7) mg/L. These results indicate that organic matter enters the river flow on a large scale, starting in the MS to DS zone.

Based on land use characteristics along the riverbanks, the US zone is dominated by vegetated land in the form of agriculture/plantation with few houses. In the middle zone, there is a change in the function of vegetated land into open land and residential areas. While the DS zone, all riverbanks are densely populated settlements. The high value of BOD_5 in the middle and DS zones is due to the entry of organic matter from human activities, agricultural and commercial waste. Domestic waste mainly comes from the kitchen, washing, and toilet waste [9].

BOD_5 is an indicator of river water pollution. Fig. 4 shows that the PI parameter of BOD in the US zone is still below QS, but height increases in the next zones to not meet QS (3.93 and 5.57). In Fig. 4d), it can be seen that BOD_5 is a parameter that causes the high PI value of the Way Kuripan River water.

Based on Table 2, the Way Kuripan River is classified as C-grade, so it can use for freshwater fish farming, farming, and irrigation. However, compared to Fig. 2a), only the US zone still fits the designation. The next two zones can only be used as irrigation water because they have been polluted and should be included in grade-D. If the BOD_5 value >15.0 mg/L indicates a heavily polluted river [30]. The high BOD_5 in the DS zone is influenced by the reduction of microorganisms so that the biochemical breakdown process does not occur significantly. In natural conditions, this effect is always caused by some toxic components that adversely affect the enzyme activity of microorganisms [31].

COD is the total oxygen required to chemically oxidize organic matter, both easy and difficult to degrade biologically. COD is also used as a measure of the pollution strength of wastewater. The COD measurement results in the waters of the Way Kuripan River are 44.1 mg/L; this is still below the QS (50 mg/L). However, if grouped by zoning, the DS

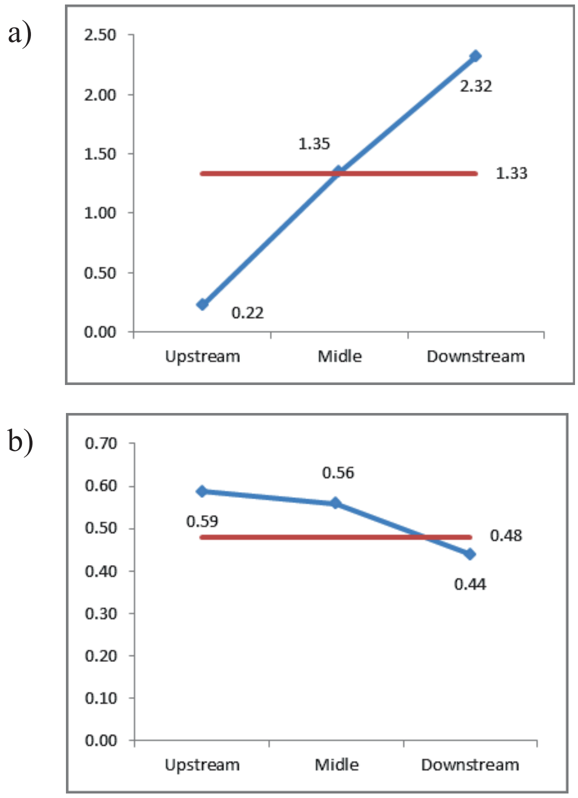

Fig. 3. Pollution Index a), and Biodegradables Index b) of Way Kuripan River.

zone has exceeded QS. Meanwhile, the US and MS zones are still below QS. The increase in COD in DS was 13 times that of US and twice that of MS. These results indicate that the entry of organic and inorganic materials is mainly in the DS zone. The types of waste that affect the high COD in waters come from household, agricultural, industrial, or livestock waste [9]. According to Both et al. [32], the high pollutant downstream is cumulative since from the upstream. Based on land use characteristics, the DS zone is a densely populated settlement with very diverse activities.

Although the Way Kuripan River is in grade-C (Table 2), from Fig. 2b), it can be seen that the DS zone is no longer follows the designation, so it is in grade-D. This result is confirmed in Fig. 4c), which shows that the PI of the COD parameter is greater than 1.0. Likewise Fig. 3, the DS zone is included in the category of low polluted (PI = 2.32) and average biodegradable (BI = 0.44). According to Ngang and Abgazue [33], if the ratio of BOD_5 and COD in water is more than 0.5, the water has been polluted. The COD value indicates the total content of organic substances (biodegradable and non-biodegradable) [34].

The results of the study (Table 2) found that the TSS in the waters of the Way Kuripan river was 115.0 (40.0-270.0) mg/L, still below the QS (400 mg/L). Based on zoning (Fig. 2c), TSS still met QS in all

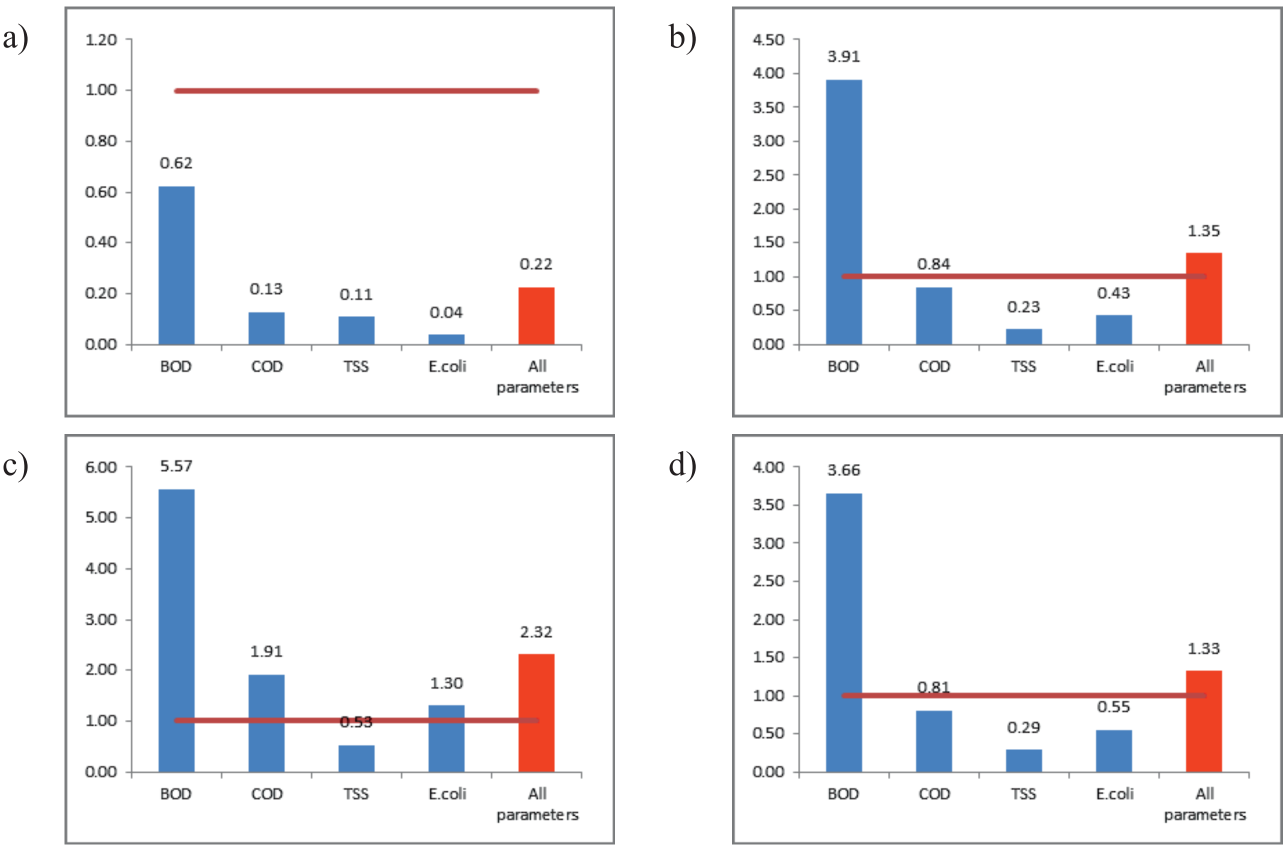

Fig. 4. PI by parameters in a) US, b) MS, c) DS, and d) General.

three measurement zones (US, MS, and DS). Similarly, from Fig. 4, the PI values are 0.11, 0.23, and 0.53, not indicating a polluted condition.

TSS indicates the number of suspended solids in water. TSS consists of silt and microorganisms mainly caused by soil erosion carried into river flows [35] and residential and agricultural waste [36]. The low value of TSS in the waters is because sampling is not carried out during in rainy season, so the source of pollution is only residential areas. According to Rahayu et al [37], high rainwater runoff will transport soil particles (topsoil) and organic and inorganic waste into the waters.

The concentration of *E. coli* content is an indicator of pollution from human waste. So if *E. coli* is found, it is believed that the water contains pathogenic bacteria [38]. Bacteriological contamination can cause serious public health problems and spread rapidly, such as typhoid fever, dysentery, and enteric viruses [39, 40]. Therefore, people living in watersheds are susceptible to disease from polluted river water.

The measurement results (Table 2) show that the total *E. coli* in the waters of the Way Kuripan River is 1107.9 (23.5-2400) MPN/100 mL. Generally, it is still below the QS grade-C river (2000 MPN/100 mL). However, the DS zone has exceeded the QS if grouped by zoning (Fig 2d). Meanwhile, the US and MS zones are still below QS. The increase in *E. coli* in DS was 32 times that of US and almost three times that of MS. These results indicate that defecation in the river is still the behavior of some residents in the DS zone. Based on land use characteristics, the DS zone is a densely populated residential area.

Although *E. coli* was found in the previous zones (Fig. 4), the status was contaminated with E. coli in the DS zone (IP = 1.30). According to Prayitno [14] and Michiani & Asano [15], buildings along the river cause various environmental problems because they dispose of their waste directly into the river, including human waste. Supposedly, public bathrooms and toilets are equipped with sewage treatment and septic tanks so they do not pollute river water. In addition, washing activities on the river banks, which are a habit of riverbank residents, deserve attention because they are harmful to environmental health [15]. The minimum distance of the septic tank to the river is a problem. In dense and slum settlements, limited land causes the distance to be less than 10 m [30].

Based on Fig. 2, the BOD_5 in the DS zone is relatively high (3.69-37.7 mg/L); this indicates a high content of organic matter as a source of life for microorganisms. Pathogenic microbes in water will increase if the organic matter content in the water is high enough as a place and source of microorganism life [34].

Given the importance of the Way Kuripan River as raw water for WTP, it is necessary to improve it from the US zone. Maintaining and increasing the area of vegetated land in the catchment area is an important work that must be done in the US zone. Improvement of the catchment area is a work that must be done to maintain and improve the quality and flow of river water [41], in addition to increasing the volume of groundwater [42]. Education campaigns not to defecate in rivers must be carried out to residents along riverbanks and not throw garbage into rivers.

Domestic wastewater treatment systems and septic tanks should also be implemented to prevent the entry of organic matter and human waste into the river. Sewage disposal is a significant component of water pollution, contributing to oxygen demand and nutrient loading of waters; promoting toxins, algae multiply and leading to unstable aquatic ecosystems [19]. The decentralized wastewater treatment system can be an economically efficient option [11]. The model can be applied in dense areas by building access roads, installing septic tanks to avoid river pollution, and planting trees along riverbanks to avoid soil erosion. The strengthening of land use regulations on riverbanks must also be carried out to ensure order and prevent extreme land-use changes.

Conclusions

In general, the water quality of the Way Kuripan River has been experiencing pollution for the grade-C rivers. However, if grouped by zoning, the contamination status only occurs in the downstream zone (DS) for all variables studied, except for the BOD_5 variable, which has exceeded QS, especially in the middle stream (MS). The PI value evidences this result in each zoning for all variables studied. The large influx of organic matter in the MS zone has occurred due to changes in land characteristics, especially in new residential areas. The main source of pollution comes from domestic waste (kitchen, washing, and latrine). In the DS zone, contamination has occurred from inorganic waste originating from densely populated land areas. From the PI value obtained, improving and optimistically restoring river water quality is still possible. Controlling the area to be in accordance with regional spatial planning regulations followed by a conservation movement for catchment areas is a very urgent action for restoring and improving the river water quality. In addition, it is more urgent to conduct campaigns and education to change people's behavior so that they do not defecate in rivers, treat household waste, use septic tanks, and recycle domestic waste.

Conflict of Interest

The authors declare no conflict of interest.

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